BULLETIN 109—January, 1896.

Cornell University—Agricutural Experiment Station,

ITHACA, N. Y.

HORTICULTURAL DEPARTMENT.

GEOLOGICAL HISTORY

OF THE

CHAUTAUQUA GRAPE BELT.

By R. S. Tarr.

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BULLETINS OF 1896.

106. Revised Opinions of the Japanese Plums.
107. Wireworms and The Bud Moth.
108. The Pear Psylla and the New York Plum Scale.
109. Geological History of the Chautauqua Grape Belt.

CORNELL UNIVERSITY,
ITHACA, N. Y., *January* 1, 1896.

The Honorable Commissioner of Agriculture, Albany.

SIR: One of the most obvious circumstances connected with the cultivation of many fruits is the fact that the most successful plantations of them are confined within somewhat narrow areas or in well marked geographic regions. This circumstance is emphatic in the grape belt of Chautauqua county. It becomes a matter of great importance to determine the reasons for the existence of these fruit belts, and to ascertain how far their limits may probably be extended with profit. A study of the surface geology and topography of any of these belts may be expected to afford most interesting and valuable facts for the pomologist, for this type of investigation is yet practically untouched by scientific inquiry. In Chautauqua county there is a particular reason for such an inquiry because of the fact that the entire Erie slope is not equally adapted to the grape, although vineyards have been almost promiscuously planted upon it. It is necessary that the true grape belt be delimited and charted. In seeking to take up this investigation, we have been fortunate to secure the services of R. S. Tarr, Professor of Geology in Cornell University. It is a happy circumstance that Chautauqua county, which originated and matured the movement for Experiment Station extension work, should now be the scene of the first specific attempt in this country, on the part of an Experiment Station, to analyze the physical geography of a fruit belt.

L. H. BAILEY.

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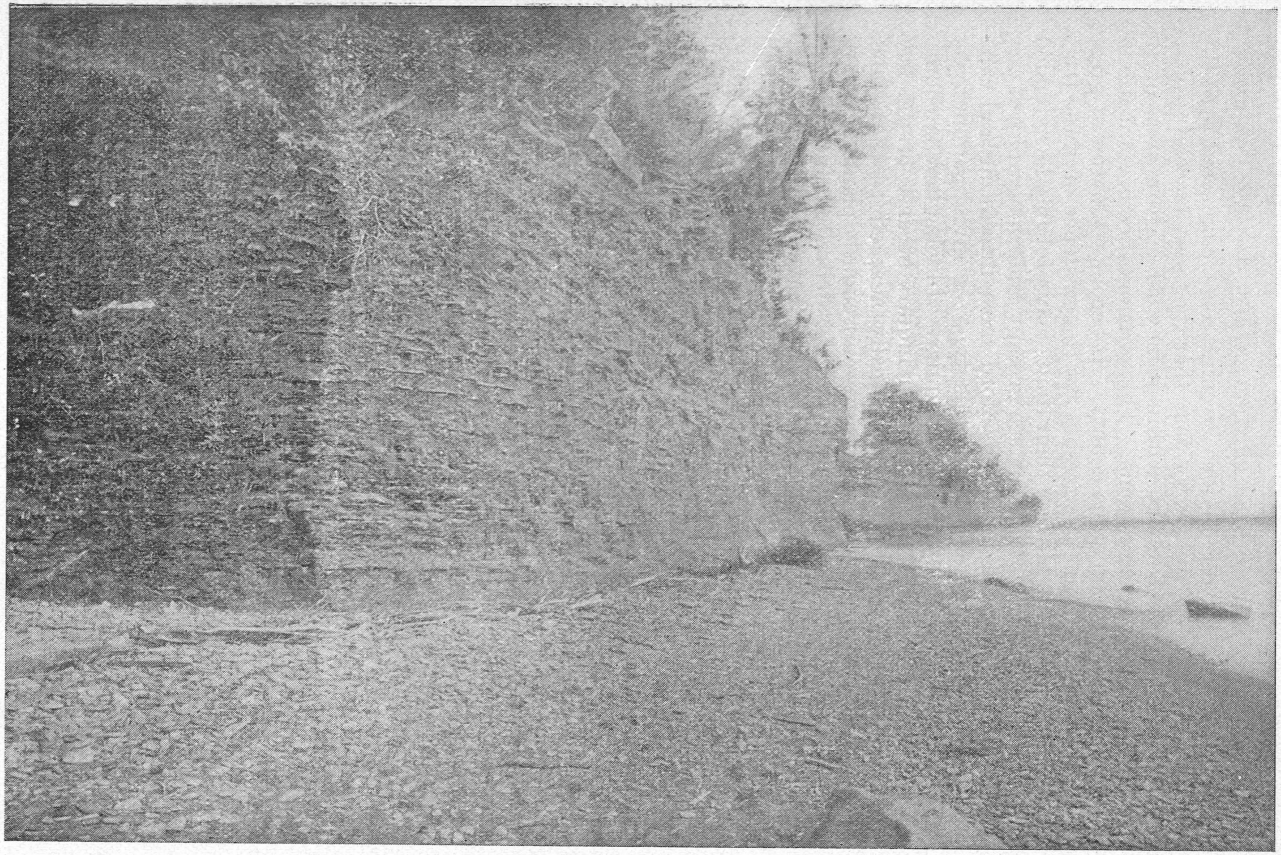


48.— Wave-cut cliff and beach of Lake Erie, north of Ripley.

Geological History of the Chautauqua Grape Belt.

Introduction.

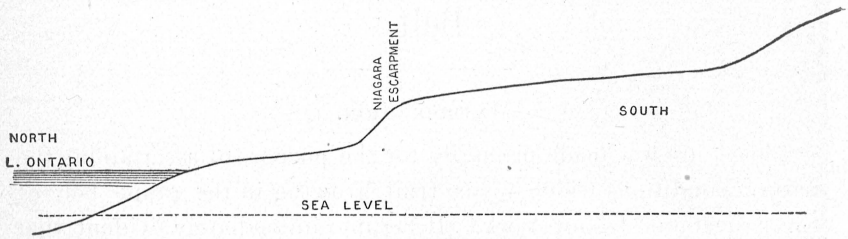
This study was made primarily for the purpose of ascertaining the natural conditions which favor fruit growing in the grape belt of the Erie shore of New York. It became immediately evident that these conditions had to do both with the soil and the climate. Concerning the latter, little detailed information of value could be obtained; for in order to gain this information, meteorological observations must be carried on for a series of years at stations located in different places. In order to find out how the soil varies, a rather careful study of characteristics and distribution was made, and the satisfactory study of these involved the question of origin. Since the origin is a question of some interest, it will be included in this paper.

In general, it may be said that the two factors of soil and climate have conspired to make the grape belt a district admirably adapted to fruit raising. While each is of importance, it is evident that the climatic peculiarities are of more importance than the soil. Both the characteristics of climate and soil are due to the topographic peculiarities and the geological history of the region included within the grape belt and in its immediate neighborhood.

The time occupied in the field study has amounted to only about three weeks — two in June, one in September and two days in November — and therefore a great amount of detail can not be expected. Although a little work was done east of Silver Creek, the study was practically limited to the region between this town and the state line. During the study, I have received many courtesies from the residents of the grape belt, and I am particularly indebted to Mr. J. W. Spencer, of Westfield. In September I was aided by Mr. T. L. Watson, of Cornell University. In running the three lines of levels, Mr. M. D. Tennant, of Westfield, did the leveling and the writer acted as rodman.

TOPOGRAPHY.

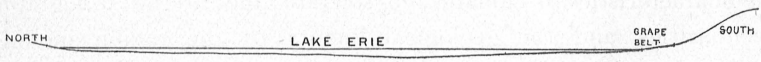
The situation of the grape belt is peculiar. From Lake Ontario southward, toward Niagara Falls or Lockport, there is a nearly level plain extending to the base of the Niagara escarpment, known



49.—Profile of the Niagara escarpment.

locally as "the mountain" (Fig. 49), which raises quite abruptly to a height of two or three hundred feet. This escarpment is well seen at Lewiston, where the basal plain stretches away toward the lake with scarcely any diversity to break the monotony. All of this plain is less than 500 feet in elevation above the sea, and it borders the entire southern shore of Ontario.

South of the Niagara escarpment, toward Batavia or Buffalo, there is another plain, which beyond Buffalo narrows down to a width of only one or two miles as the state line is approached. It is nowhere below 500 feet, nor above 800 feet in elevation. This narrow strip which borders the Erie shore is the true grape belt. Everywhere the southern margin of this plain is backed by an



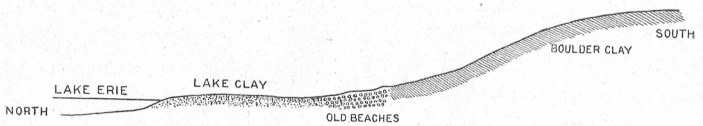
50.—Location of the grape belt.

escarpment or ridge (Fig. 50), which quickly raises to a height of 500 or 600 feet above the plain, and in some places is over 1,000 feet above the lake. Therefore, the grape belt (in New York) is a narrow plain extending north-eastward from the Pennsylvania state line, and bounded on the north by the lake, on the south by a high range of hills. East of Silver Creek the plain widens and the bounding escarpment loses in elevation. This narrow plain is only a small fragment of the real plain; for the waters of Lake Erie cover the greater part of it. As is shown in the profile (Fig. 50), the plain descends beneath the lake waters

and ascends on the Canadian side. Not merely is a part of the plain now submerged, but at a recent geological period more of it, and that part now occupied by the most flourishing vineyards, was covered by the lake waters. Lake Erie now plays an important part in modifying the climate of the grape belt; it formerly did important service in modifying the soils.

THE BED ROCK.

As revealed along the lake shore, and in the remarkable gorges which cut the escarpment and the plain, the bed rock is entirely upper Devonian shales and sandstones above the horizon of the Hamilton, which does not extend farther west than Evans. Both plain and escarpment are made of these; but it is probable that the latter owes its elevation to the protective effect of some harder layers of upper Devonian rock now removed.

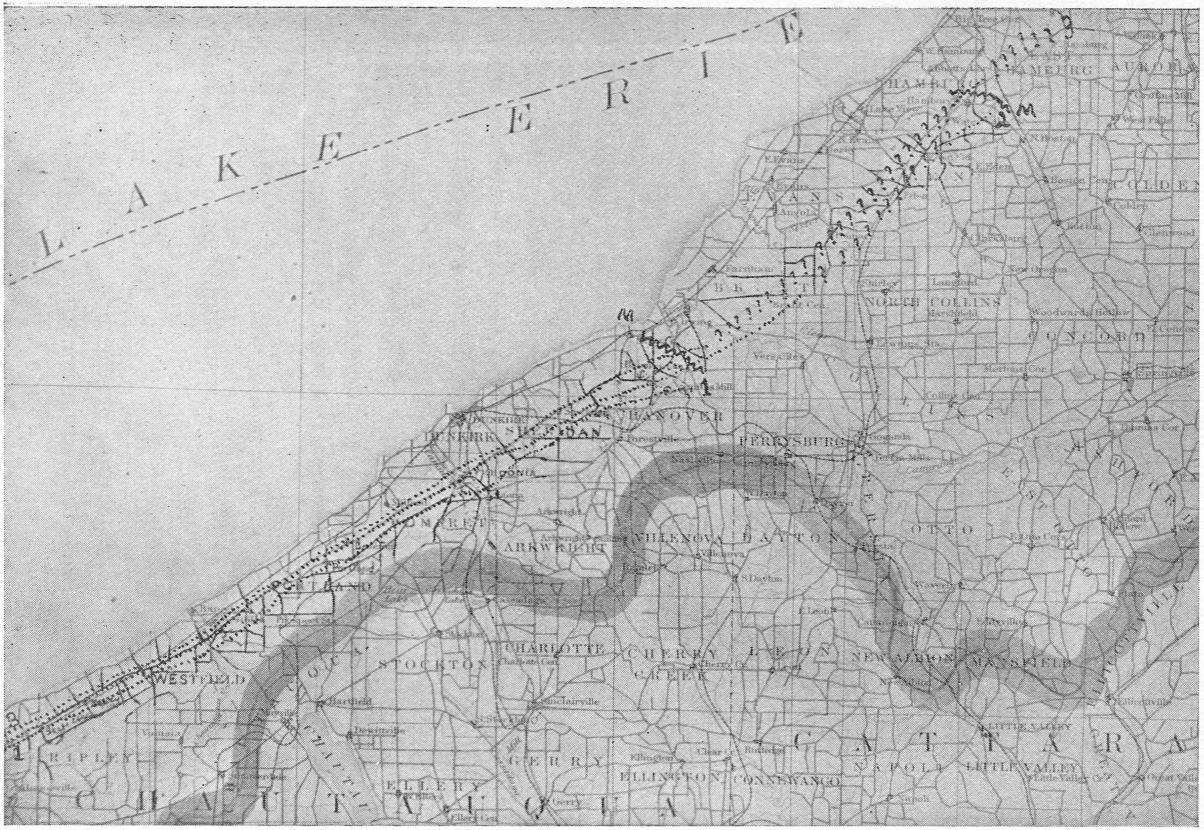


51.—Section of the grape belt.

On the northern face of the escarpment the soil is prevailingly thin and the plough frequently reaches the bed rock; but on the plain, the bed rock is rarely seen at the surface, excepting in the stream beds and in the shale ridges, which are found mainly east of Dunkirk. Still the bed rock plays an important part in the soils; for fragments of shale are commonly present in all the soils of the district.

THE SOILS.

General description of the soils.— If we should make several north and south sections across the grape belt, from the middle of the escarpment to the lake shore, they would be found to vary in details according to the location of the line, but to be quite the same in general features. The average condition would be as follows (Fig. 51). Commencing on the hillside with a thin soil of clayey nature, and with an abundance of pebbles, (Fig. 53) and perhaps boulders, at the base of the hill, when at the elevation of about 250



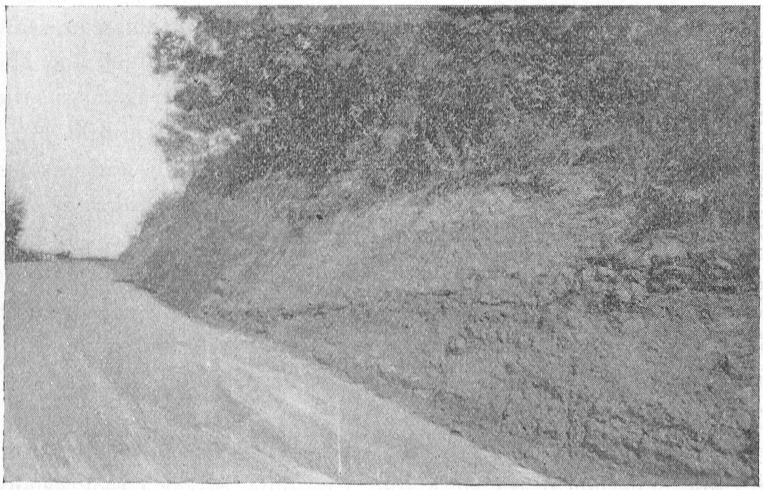
52.— Map of the region in the vicinity of the Grape Belt. Showing the approximate location of the three beaches and the moraines (M).

feet above the lake, we come to a gravelly soil in which the pebbles are well rounded (Fig. 57) as if by water action. North of this there is a steep slope of twenty or thirty feet, at the base of which the soil becomes clayey, and this continues usually for several hundred feet, or possibly as many yards, when gravelly conditions are again encountered, somewhere in the vicinity of the main Buffalo and Erie turnpike. One or two gravel terraces are found here, and at the base of the northernmost of these clay again appears. Here, as in the case of the first gravel ridge, there are springs at the junction of the gravel and clay, so that, where not artificially drained, this place is continuously indicated by swampy conditions. From the top of the upper (southernmost) gravel ridge to the spring line at the base of the lowest the descent is about ninety feet, and the distance anywhere between two and three hundred yards and a mile or even more, though usually not far from a quarter of a mile.

From this point lakeward, a distance of one or two, and in some places even three miles, the plain is somewhat irregular, with a general descent toward the lake, which is some 150 to 160 feet below the gravel ridges. The soil is usually a clay, though it is often of a sandy nature. The immediate shore line is commonly a bluff, either of shale or of clay (Figs. 48, 59 and 61), though at times it is in the form of a beach, without any well-developed bluff (Fig. 58).

As has been said, this will hold in general for *any* north and south line, whether at the state line, Fredonia, Silver Creek or any intermediate point. If, however, we make our section nearly parallel to the lake shore, remaining at the same elevation above its surface, we find a remarkable uniformity of conditions. Thus we may pass from Erie, Pa. (and indeed from far to the west of this), to Hamburg, N. Y., without leaving a belt of gravel, excepting where the road crosses a stream; or, if on the hillsides, one may pass over the same distance upon a boulder-bearing clay; or, if near the lake, upon a fine clay soil, usually free from boulders. These differences are constant and they are due to definite causes. Since the result is of importance to the fruit grower, the cause must at least be of interest. Before considering the cause, we will examine the conditions in a little more detail.

The hillside soils.—Above the upper gravel (see map, Fig. 52), which usually lies but a short distance south of the main road, the ground generally commences to rise more rapidly and the escarpment is soon reached. On this hillside there is considerable grape raising, but the soil is altogether different from that in the region to the lakeward, which is the main grape belt. The base of this soil is a clay of very fine texture; but there are some local variations from this. In some cases the soil is a loam and in places it is even sandy, while on the other extreme it is often a dense hardpan; but nearly everywhere the bulk of the soil is clay, whether it is



53.—Section in the boulder clay on Mayville and Westfield road.

hard and compacted into hardpan or is a loose and relatively friable loam. When fresh, the color is blue; but since the soil is generally somewhat disintegrated, the color ordinarily seen is a yellow, which is due to iron rust leached from the soil fragments.

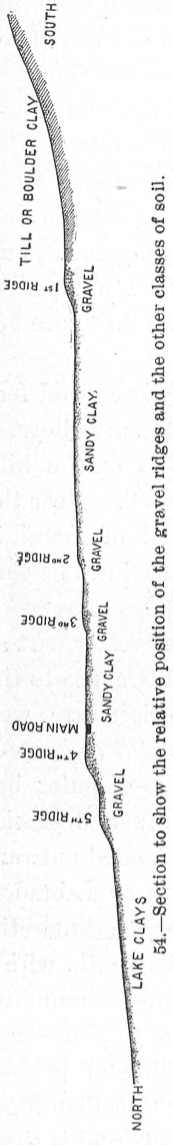
Next in importance to the clay is the presence of pebbles. These are very numerous, and at times they are of considerable size. It is important to note the form of these. They are angular, and if rounded at all, this is usually on only one or two of the sides, so that angular corners are almost invariably to be found. Moreover, the sides of these often bear numerous grooves and scratches. While many of the pebbles are fragments of shale rock,

like that which forms the bed rock of the region, a careful examination shows that there are many which are foreign to this part of New York. Thus granites, sandstones and limestones are found in a region which from the bed rock yields only shales and sandy shales. If we could examine the soil particles with a microscope, we should find them to be composed of minute rock particles, fresh and unchanged, as if worn or ground from the rock by some strong force. The entire mass is put together without arrangement, and there are no distinct layers such as those found in the lower gravel soils. We say it is unstratified, though sometimes (as in figure 53) there is a partial stratification, never very distinct.

This soil varies greatly in thickness, being usually several feet deep; but while sometimes, particularly in the stream valleys, it attains a depth of several hundred feet, in other places on the hillsides it forms a very thin veneer over the shale rock. Near the crest of the escarpment there is another belt of soil of morainic origin; but as this is not in the true grape belt, it need not be considered here.

This clay soil is the same as that which covers the greater part of the area of New York and New England, and of Canada to the north of these districts. Its characteristics and origin are well understood by geologists, to whom it is known as *till* or *boulder clay*. In the first half of this century its origin was in dispute; but we now know that it is a deposit from a great continental glacier which occupied northeastern North America, and extended outward in all directions from a center near Hudson Bay or Labrador, behaving like the present ice sheet of Greenland, or the Antarctic. Slowly moving across New York State, toward the south, with a depth certainly as great as a mile (for it covered the highest mountains of the east), it ground down the rocks, reducing them to a fine clay, which is often called rock flour, and caused a mingling of pebbles from various sources. Thus the granite from the Canadian highlands is stranded on the hillsides of Chautauqua county and is there mingled with the shale. The grooved and scratched pebbles show that this process of grinding was in operation.

Much of this material was dragged beneath the ice; and owing to variations in the topography of the land, in currents or in supply,



54.—Section to show the relative position of the gravel ridges and the other classes of soil.

in some places it accumulated to a depth of several hundred feet, while in other places it was not so extensively deposited, just as in some places a river scours its channel clear, while elsewhere it is building a bar. Finally the ice disappeared from these hillsides and all of the material that was in or under it was left to form the present hillside soils.

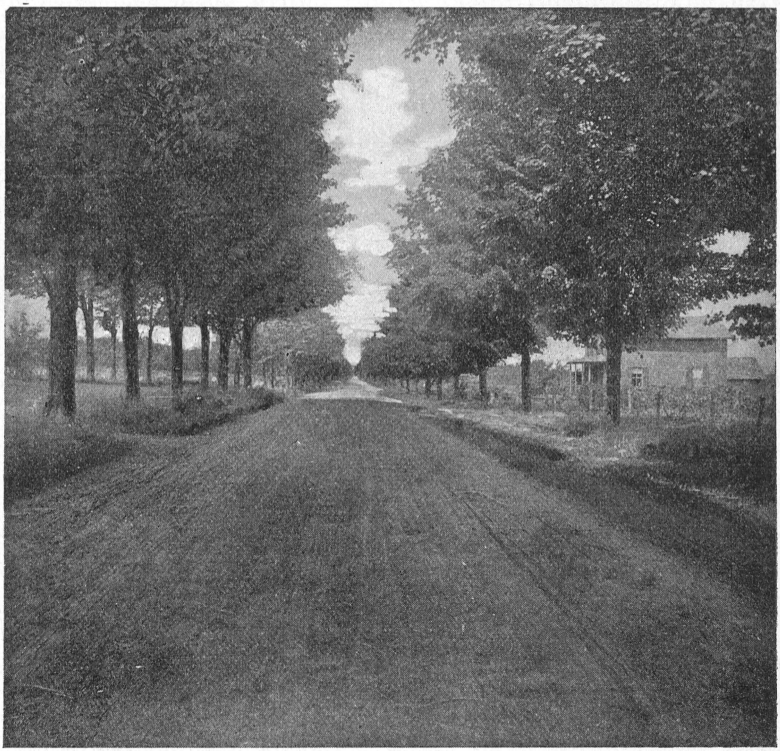
The hillside soils are somewhat difficult to work, partly because of the roughness of the surface, partly because of the irregularities of the texture and composition, which, even in the same field, may very differently affect capillarity and drainage. Moreover, it is often a dense hardpan which is difficult to till. Still it is a strong, sturdy soil, which, when properly cultivated, furnishes good crops. However, it is not so well adapted to grapes as the more sandy soils of the valley.

The gravel ridges.—Throughout the entire grape belt (Fig. 54), there are three distinct gravel areas, extending approximately parallel to the Erie shore. On one of the two northernmost of these the main road to Buffalo is generally located, while the third is south of this, at distances generally varying from one or two hundred yards to more than a half mile. Between these distinct ridges there are sometimes one or two less distinct gravel beds; but most of the space between them is occupied by a clayey soil. In some places, particularly near the larger streams, the entire belt is gravelly.

The surface of the gravel ridges is typical. Each one is remarkably level-topped (Fig. 55), and the roads that follow them often extend for miles almost on a dead level. There are distinct terraces, and when viewed from the north they present a bold face which rises quite abruptly to a height of from fifteen to thirty feet (Fig. 56), beyond which a nearly level plain is usually encountered (Figs. 54 and 55). Near the streams the terrace is broader than elsewhere; and in some cases it is a true

ridge with a nearly level top but with a slope both to the north and the south (Fig. 65).

The soil of these gravel ridges is peculiar, and it is upon them that many of the best vineyards are located. Wells and natural sections show that the gravel soil varies in depth from one or two feet near the edge, to ten or fifteen feet. Beneath the gravel is found clay or shale. The gravel soil consists of pebbles and sand



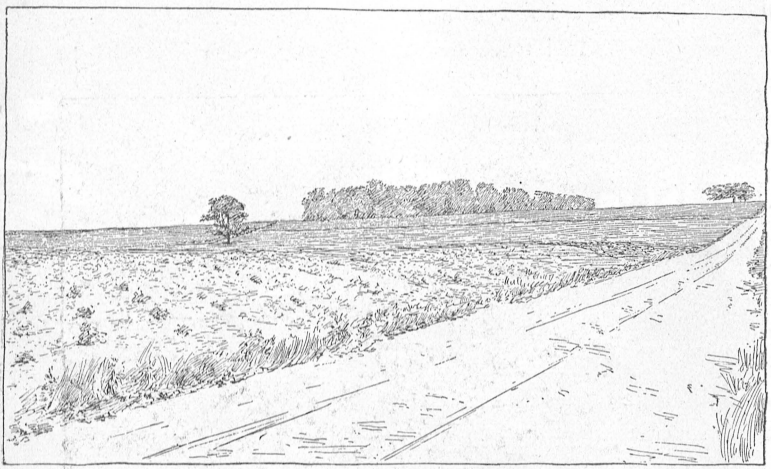
55. — Round the crest of a gravel ridge just east of Fredonia.

with scarcely any clay, excepting that which has come from the disintegration of some of the fragments. After plowing it does not form clotted bunches, but is loose, friable and porous. Water readily passes through it, and for this reason, forms of vegetation whose roots do not extend deep into the soil are in danger of suffering in times of drought.

When examined in a fresh section, it is found that the gravel is often very pebbly, and that the pebbles are sometimes very large.

Compared with those of the hillside, the pebbles are found to be well rounded and smoothed (Figs. 57 and 66), as if by water action. There are few if any angular corners, and no grooves or scratches. The clay element is practically absent, and the pebbles are bound together by sand instead. The pebbles and sand are in layers, or are stratified (Fig. 57), so that there are several important differences between the soils of the two zones.

A comparison with the beaches of the present lake shore shows a striking resemblance, not only in texture but in the surface outline. In both cases there are many rounded pebbles and much sand; and in both cases, also, the surface form is that of a flat-topped



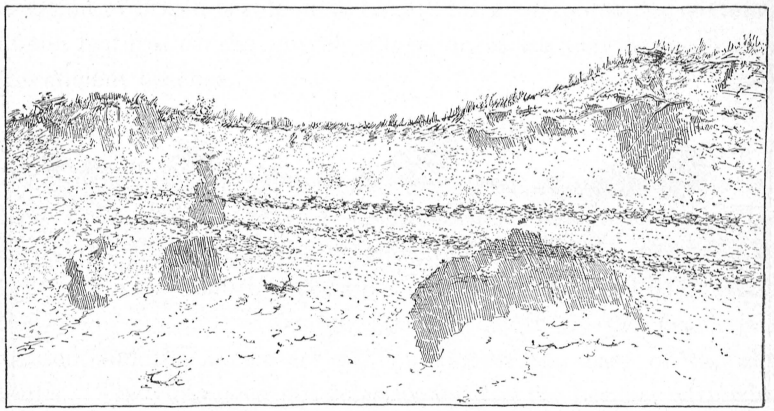
56. — Upper terrace southeast of Sheridan.

terrace. However, in the beach there is almost no clay, while in the gravel ridges the decay of some of the pebbles and sand particles has furnished some clay; and also the action of vegetation and cultivation has somewhat modified the gravel ridge soil. The meaning of this resemblance will soon be shown to be similarity of origin. As many who have tilled the gravel soil have conjectured, the ridges are true lake beaches now stranded on dry land.

The lake clay soils.—In the present lake, gravel beaches are being formed along the shore line; and each time that there are strong waves, the washing action of the water moves the pebbles backward and forward, rounding them by grinding off tiny particles of clay. The force of the waves and currents is capable of carrying

the beach sand and gravel only to a very short distance from the shore line; but the clay that is worn away by the waves passes in suspension for a considerable distance from the shore line before settling to the bottom. During windy days the waters immediately off shore are clouded with sediment. Fishermen know that at a distance of only a few yards from the shore the lake bottom is almost everywhere covered with clay or sandy clay. The soundings made by the United States Engineers, who have surveyed the bottom of Lake Erie, show that a muddy bottom is the prevailing feature.

When the lake waters reached to the height of the gravel ridges, the region below this was naturally a place for the deposit of clay.



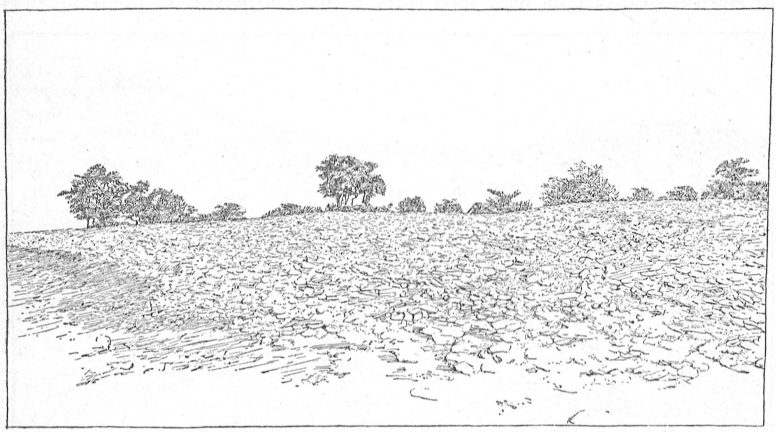
57.—Section through the upper beach at Westfield, showing stratification of pebbles and sand.

While some pebbles may have been drifted away by the ice, and dropped to the bottom away from the shore, the clay was in most places free from large fragments. In some places, particularly opposite the mouths of streams, the clay might be replaced by sand for a considerable distance from the coast. An examination of the soil between the northernmost gravel ridge and the lake shore, shows that these features exist.

A layer of clay, varying in depth from a few inches to several feet, is spread over most of the region west of Silver Creek and north of the gravel ridges. Oftentimes it rests on the bed rock, barely covering it: in other cases it is found above the true boulder clay, and in some stream cuts one may often see a bed of dense boulder clay upon which rests a foot or two of clay, which

is often quite sandy. In such places, one has the opportunity of studying the differences between the two kinds of clay soil, one of which is characteristic of the hillsides. The lake clays are found to be in layers, as if deposited in water, and the clay is usually less dense than the boulder clay, while pebbles are relatively scarce.

Shale gravel.—Between the lake shore and the true gravel ridges, in some places there are low ridges of shale, on which the soil is so thin that deep plowing reaches the friable shale bed rock. The soil is then made up of a mixture of fragments of shale and clay, forming what is known as shale gravel. These deposits are not



58.—Modern beach at Barcelona, showing the crest in the background.

very extensive, and they merely represent rock hills which have not been deeply covered by glacial or lake deposits. They are less common west of Silver Creek than they are east of that town.

The relative value of the soils.—Of the three important kinds of soil in the grape belt, the gravel is distinctly the best for fruit raising, and the hillside soils of the least value. That the fruit growers have generally recognized this, is shown by the fact that in the belt of gravel there is a much greater percentage of vineyard than in either of the other belts. While it is so readily permeable to water that plants whose roots do not extend deep into the ground may suffer from droughts, it rests upon a much less permeable rock or clay, over which water is constantly percolating; and those forms of vegetation whose roots are able to reach down to this zone are

not endangered. The depth of this permanent water zone is variable, but it is usually several feet.

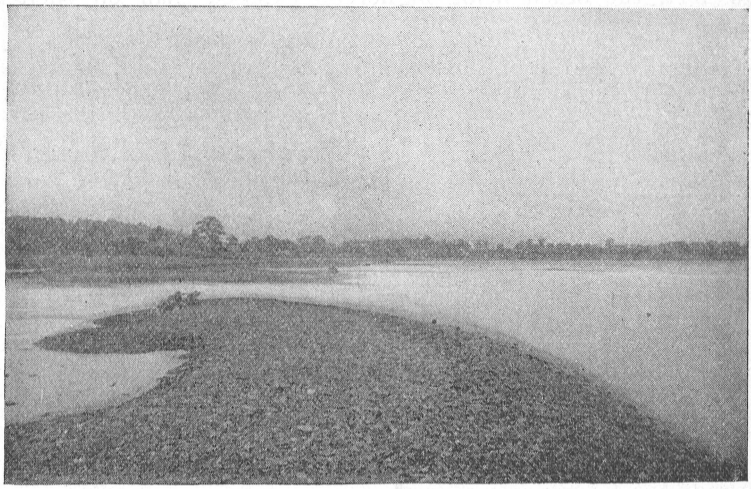
The width of this gravel belt is very variable, as indeed are the details of its composition. Near the mouths of large streams, as at Silver Creek, Fredonia, Westfield and the state line, the zone broadens so that a sandy soil extends from the base of the true gravel ridge across the plain, nearly, if not quite, to the lake. Between the streams the gravel ridges become narrower terraces, and the lake clay soil commences at their very base. Therefore, in different parts of the grape belt, the area in which the soil features are especially adapted to grape raising is somewhat variable; but there is a certain uniformity, and the importance of this to the question of origin is sufficient to call for a more detailed statement of the features of the gravel ridges, or, as we may now call them, the ancient beaches.

THE MODERN BEACHES.

Let us first take a glimpse at the present shore line features of Lake Erie. There are two separate kinds of shores, the rock or clay bluffs (Fig. 48) and the gravelly or sandy beaches (Fig. 61). Oftentimes the bluff is faced by a beach (Figs. 48 and 61). Where the larger streams enter the lake, the width of the beach is increased, and the waves are not cutting at the base of the shale bluffs. The cliffs need not delay us, for it is the beaches with which we have to do in particular. The beaches consist of sand and gravel thrown by the storm waves to a height of several feet above the reach of the ordinary waves. In time of strong waves the water dashes over the top of the beach, moving the pebbles to and fro, although they are situated fully ten feet above the present lake surface (measured at Barcelona) (Fig. 58). This is the crest of a terrace whose width varies, sometimes being a narrow strip at the base of a bluff (Fig. 59), sometimes, especially near the mouth of a stream, broadening out to quite an extensive plain. At Silver Creek and at the mouth of Cattaraugus Creek, the beach deposits are very extensive; and in the latter, the action of the wind by building sand dune hills has raised the level above the reach of the highest waves. In these places also, bars are being built opposite the mouth of streams (Fig. 60).

59.— Crest of modern beach at Barcelona with a clay bluff in the background.

The reason why these beaches are being built is that the supply of gravel is greater than the waves are able to remove. In some cases the supply comes mainly from the rocky headlands, in others



60.— Present bar formation at Silver Creek.

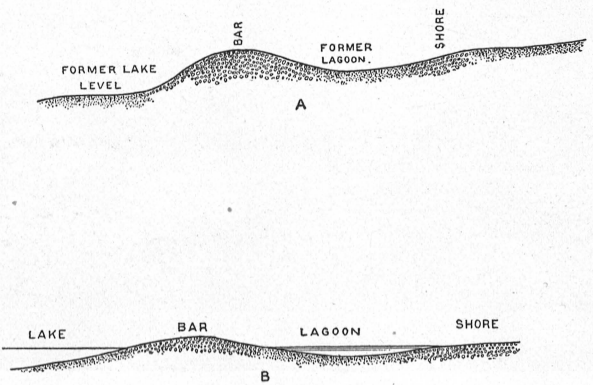
from streams. Where it can not all be ground down to a fine clay, that can be carried off shore and dropped to the bottom, it accumulates as beach gravel; and so, year by year, the beaches encroach

61.—Present beach of Lake Erie, north of Dunkirk.

upon the lake. The crest of the beach, which may be ten feet above the lake level, represents the highest point to which the lake waves can reach and bear gravel: in other words it represents the

height reached by the violent storm waves. Since this varies with the exposure, the crest of the beach may vary in height, as we have seen that it varies in width. This variation amounts to only a few feet, the beach being higher on exposed than on sheltered coasts.

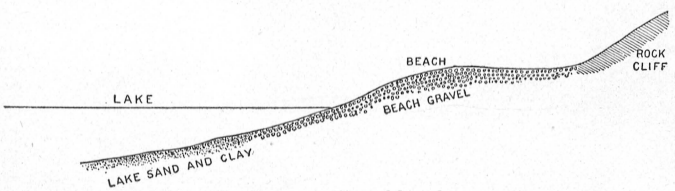
Generally the top of the beach is nearly level (Figs. 59 and 61);



62.— Cross section of bar: ancient A ; modern B.

but where accumulations are made off shore, as they sometimes are where streams bring considerably more gravel than the waves can dispose of, a bar is built, and this slopes both ways (see Figs. 60 and 62B. Also compare with Figs. 62A and 65).

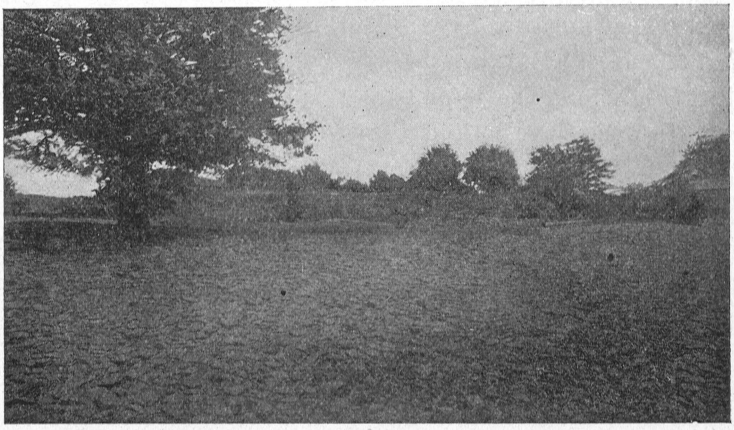
Therefore the top of the true beach is a plain of varying width, whose elevation is nearly uniform, both along the shore and at



63.—Cross section of beach.

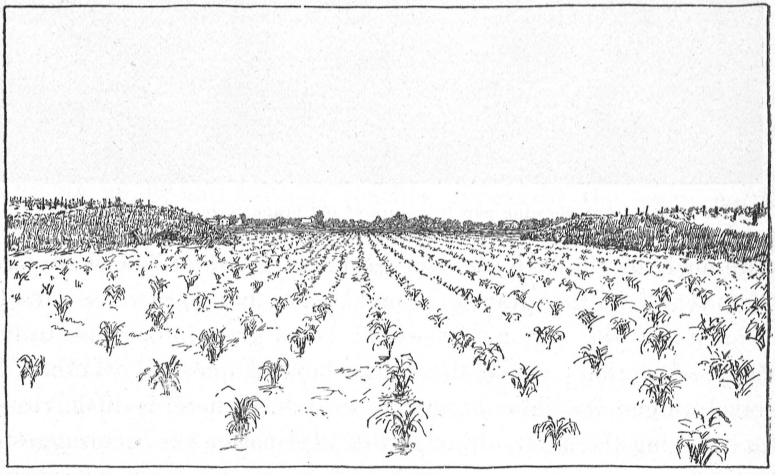
right angles to it. If it is in the form of a bar, the elevation remains nearly uniform in the direction of the length of the bar, but at right angles to this it rapidly descends in both directions. In the beach, the flat topped plain is faced on the lakeward side by a rapidly sloping front; and this descent continues beneath the lake waters. (Fig. 63).

Therefore on the shore of the present lake we have a terrace plain of a nearly uniform level, and the terrace slope (Figs. 58, 59 and 61), the whole being composed of well rounded and water-worn



64.—Pebbles of the modern beach at Barcelona.

gravel and sand (Figs. 58 and 64). We also find numerous wave-cut cliffs either in the clay (Fig. 61) or in the rock (Fig. 48); and opposite the mouths of the streams there are often formed bars (Fig.



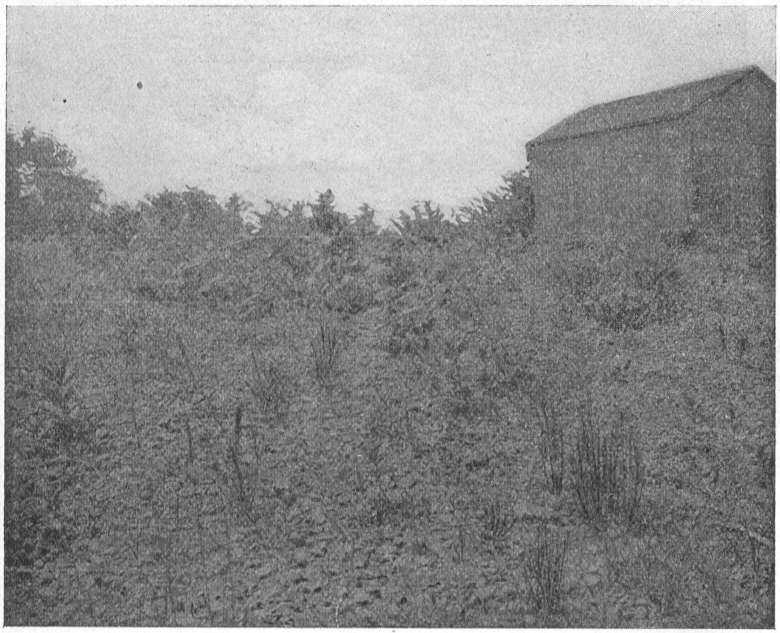
65.—Section through a bar. Midway between Sheridan and Fredonia. Beach to be seen in the background in the gap cut through the bar.

60) which are welded at their base to the beach, and stretch more or less completely across the stream mouth. Sometimes there are

spits of gravel; and there are numerous other minor details of shore line features.

THE ANCIENT BEACHES.

Most of the features just described are found also in the gravel ridges. They usually have all of the characteristics of beaches (Figs. 56 and 66), and near the streams they are often transformed to bars (Fig. 65). The resemblance is so close that even the most casual observers have noticed it and formed the theory that the ridges

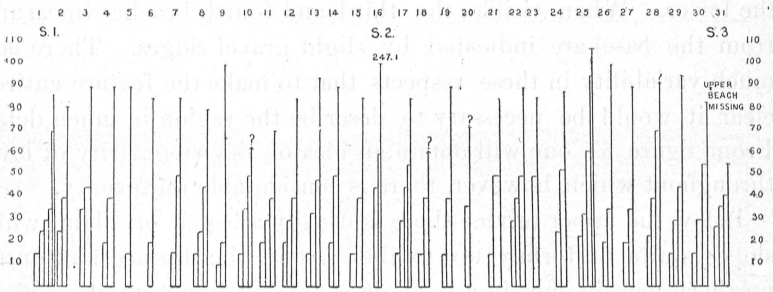


66.—Photograph showing pebbly nature of old beach terrace near Sheridan.

were made by the lake waters. So far no fossils of lake shells have been found in the gravels, though some have been reported by residents of the region. It would be of great importance to find these* for they would determine beyond question whether the gravel ridges are lake or ocean beaches. There is little reason for believing the latter, although this explanation has been suggested by some.

* If any reader should know of the existence of fossil shells like those now living in the lake, I should be very glad to be informed of the occurrence.

The gravel ridges.—In passing from one end of the district to the other, numerous differences are found in the gravel ridges. Perhaps the most important change is in the number of beaches (Fig. 67). From the base of the lowest to the crest of the highest, there is a vertical range of from 85 to 100 feet* in a distance which is often less than a half mile. In this distance there are always two distinct ridges or beach terraces and usually several. There seem to be five beaches, though it is rare to find all developed in the same section. In thirty-one sections whose elevations were measured with the aneroid barometer, only one (Number 17) clearly exhibited five ridges. In section 1 there are six gravel ridges, but one or two of these may have been bars opposite the stream mouth.



67.—Diagram to show the elevation of the different terraces (in thirty-one sections) above the base of the lowest terrace. 1, at State Line ; 30, just east of Silver Creek.

There are four beaches in section 10, in which the upper beach was not measured; and there are also four in Section 31 where the upper beach is absent. In several places (nine sections, 8, 11, 12, 13, 22, 25, 28, 29 and 30) four beaches appear in the same north and south line. On the other hand there are places where the three lower beaches are merged into one terrace, or in which one or two of the beaches are so indistinct as to be scarcely noticeable (notably section 16).

From State Line to Sheridan the upper beach is quite distinct; but east of that place this beach begins to lose distinctness and it disappears just east of Silver Creek. The lower beaches extend eastward, one

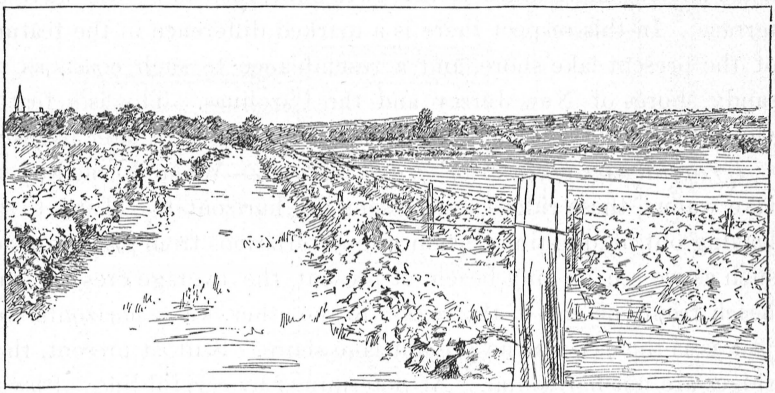
* The elevation of the lake is 573 feet above sea level ; and of the base above the lake, as determined by a line of levels run at Portland, 147 feet. Therefore at this point the base of the lowest beach ridge is 720 feet above sea level.

disappearing just south of Hamburg, the others extending to the vicinity of Crittenden where they also die out. Without analyzing my measurements here, it may be said that the crest of the first or lowest beach ranges from 15–20 feet above the base of the terrace; the second beach ranges between 10–15 feet above this; the third from 10–15 feet higher; the fourth also 10–15 feet higher; and the fifth between 30–40 feet above this. As one drives along the main road to Buffalo, the face of the upper terrace is frequently visible, while the road itself is usually upon either the lowest, or, more commonly on the second level. From just west of Silver Creek to within three miles of Fredonia, it follows the lowest; but west of this is more commonly on the upper level, though at times descending to the lower. When visible, the third and fourth beaches (measured from the base) are indicated by slight gravel ridges. There is so much variability in these respects that to make the feature entirely clear it would be necessary to describe the region in much detail. From figure 67 one will obtain an idea of the irregularity of level, throughout which, however, there is considerable uniformity.

Below the upper terrace there is usually a bench or plain which slopes quite uniformly up to the base of the terrace and on the northern margin ends in a steep descent; but in a number of places this plain is diversified by slight benches of gravel, marking some of the intermediate beaches. From the crest of the upper terrace toward the south there is also a plain, which is usually very narrow, but is sometimes gradually merged into a broad till-covered plain (Fig. 54).

From the lake shore to the base of the first gravel ridge, near the main road, there are no beaches of a distinct character, although in one or two places there are indications of wave action. Over this plain, which is often one or two miles in width, the soil is mostly of clay, as has already been noted. However, north of the town of Portland there is an ancient sand dune region, in which the sand is no longer in movement, having probably had its features introduced immediately after the lake water left the land. The sand is fine in texture, quite like moulders' sand, and it is heaped into the typical conical peaks with enclosed craters, which characterize sand dune belts. Here the topography is very rough; but elsewhere the prevailing condition is that of a plain, sloping lakeward.

Variations in the gravel ridges.— Not only do the number of the gravel ridges vary, but there is a considerable difference in their characteristics from one point to another. Generally the slope of the terrace front is abrupt (Fig. 68), and the top quite level; but, as has already been noted, it may be in the form of a ridge or bar instead of a beach. There is also a variation in width, which in some cases is very marked. Notably opposite the mouths of streams the width of the gravel is greatly increased, the deposit there being in the nature of a delta. Here the steep front of the terrace disappears and is replaced by a gravel slope, crossed by numerous gullies and traversed by ridges of gravel; and this gravel extends for a considerable distance toward the



68.—Front face of lower beach terrace just west of Portland. East of section line No. 2, Fig. 67.

lake, gradually becoming a sand, and then, near the lake, a clay. The best delta in the area studied is that upon which the town of Fredonia is situated; but there are other similar deposits near the mouth of nearly every stream of considerable size.

Just as in the modern beach, there is also a variation in texture in any single gravel ridge. But quite unlike the modern beach, the material is always a gravel. In the entire region studied I have found no considerable part of either terrace made of sand. In small areas there is often much sand; but nearly everywhere there are layers of rounded pebbles in close association.

On the present shore there are many wave-cut cliffs of shale; but in the entire region occupied by the gravel ridges, from State

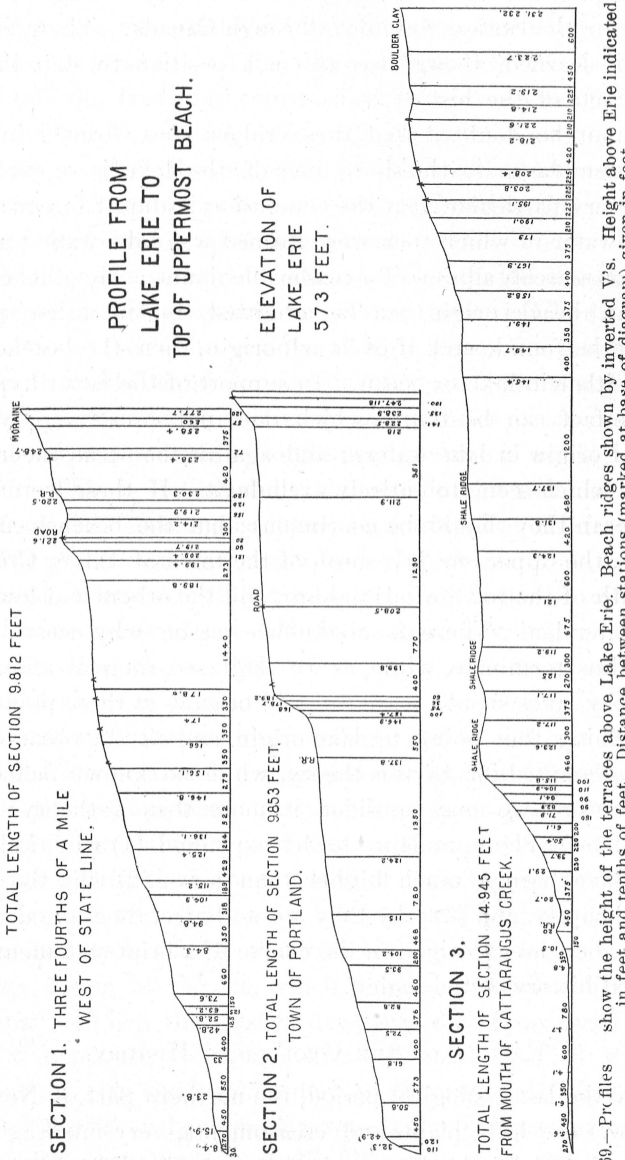
Line to Hamburg, I have not found a single rock cliff. In some cases wells have reached rock near the front edge of the gravel terrace, suggesting the possibility of such cliffs veneered over with gravel which has slipped down from above. This would be possible only with low rock cliffs; and we may therefore conclude that in this part of the shore line there are no wave-cut cliffs which are at all comparable in size to those of the present lake shore. Whether there are any wave-cut cliffs of gravel I am not so certain. There are places where the lowest terrace may be of this nature; but this could not be proved, for beach gravel covers the face and base.

In any event, it may be concluded that the prevailing feature of these ancient shore lines is the wave-built, instead of the wave-cut terrace. In this respect there is a marked difference in the features of the present lake shore, and a resemblance to such coasts as the sandy shores of New Jersey and the Carolinas. This is a feature which needs to be explained and will be discussed in later pages.

Irregularities of level of gravel ridges. — When formed by the lake waters, these ridges were essentially horizontal. That is to say, leaving out of question certain minor variations from place to place, such as we see on any beach at present, the average crest of each beach from one end of the region to the other, was a horizontal line, just as is the case on the present lake shore. Still, at present, these ridges are not horizontal. As determined by careful lines of levels, and by numerous elevations obtained by other means, they are tilted so that the eastern end is higher than the western. This necessarily records a change in the level of the land since the beaches were deposited. Along the line of beaches from Cleveland to Silver Creek the change amounts to over 90 feet. Therefore, since the distance is about 150 miles, the change in level amounts on the average to about three-fifths of a foot per mile. The levels made in the grape belt are not of decisive value for the distance between them is not great. Still in the profiles (Fig. 69) one sees that very nearly the same change is recorded.*

* From Section 1 to Section 3 the distance is 36 miles. The crest of the second beach is 185 feet above lake level at State Line, 195 feet at Portland and 221 feet just east of Silver Creek. In other words, the beach increases in elevation at the rate of about 1 foot a mile. There is little doubt that the uplift is greater in the east than in the west.

Interpretation. — For a long time we have known more or less concerning elevated lake beaches which seem to nearly surround the



69.—Profiles show the height of the terraces above Lake Erie. Beach ridges shown by inverted V's. Height above Erie indicated in feet and tenths of feet. Distance between stations (marked at base of diagram) given in feet.

Great Lakes. Different geologists have studied different sections and so we have many scraps of knowledge; but these are not suf-

ficiently complete to allow of any full statement of their meaning. Indeed, one of the needs of North American geology is to have some one person follow this subject to an end by tracing the beaches not only to the States, but also through Canada. There is much yet to be learned, though we are in a position to state the more general facts of the history.

It cannot be doubted that these ridges were formed in water. Their resemblance to the shore lines of the lake is so perfect, in almost every particular, that the conclusion is almost forced upon us that the water in which they were formed was lake water; and this conclusion scarcely admits of a reasonable doubt. No other explanation than beach origin can be admitted, for no other possible cause can be found, and if of beach origin, then the beaches were formed either in lake or ocean. In support of the latter hypothesis no single fact can be found which does not equally apply to the theory of origin in lake waters; and against the ocean theory there are facts which seem to entirely exclude it. If these were formed in the ocean they should be continuous; but the beaches end quite abruptly, the upper one just south of the town of Silver Creek, the next south of the town of Hamburg, and the others and lower ones near Crittenden. There is no known reason why ocean beaches should thus terminate, while, as we shall see, there is an excellent reason why lakes should cease to build beaches at these points.

Everything then points to lake origin, and all the observed facts may be accounted for by this theory, while no known fact opposes it. Therefore we may consider it more than a theory; it is a proved fact. There remains to be explained (1) why Lake Erie should have been so much higher than now; (2) why the beaches end so abruptly, and (3) why they are no longer horizontal. These facts can best be explained in the course of a brief statement of the geological history of the region.

RÉSUMÉ OF THE GEOLOGICAL HISTORY.

Before the last geological period, the northern part of New York had valleys and hills, plains and escarpments, very much as at present, though the details of topography were quite different. Among the more important differences was the absence of the great lakes, which occupy valleys that have been transformed to lakes largely

by the action of the glacier. Over this country the glacier ice slowly advanced until practically the whole of New York was covered, and for a time this ice sheet ground its way over the rocks, carrying fragments southward and wearing down the valleys and the hills as it passed. All life was of course exterminated from the region and the land was transformed to a dreary icy plateau like that of central Greenland. Why it came or how long it remained are questions which the geologists of the future must answer, if we ever learn. That it came and worked, performing certain tasks we of the present century have determined.

At last, by some change in the condition of the climate, the ice sheet began to melt away and to uncover the buried land. It seems to have done this quite rapidly, though somewhat intermittently. That is, it would stand for awhile with its front along a certain line, then quite rapidly melt away and transfer its front to a distance of a dozen or so miles to the north, where it would again take a stand. This is indicated by the moraines, which are irregular hills of glacial deposits that were accumulated at the front of the ice. The glacier was carrying a load of rock materials, and when these reached the front they were dropped from the melting ice and therefore accumulated. If the ice stood long enough a moraine was built along the margin; if its stand was brief no morainic accumulations were made. One of these moraines passes through Jamestown, another past the northern end of Lakes Chautauqua, Bear and Cassadaga, and in a general east and west line back of the crest of the escarpment. Another line passes just east of Silver Creek, one near Hamburg, and another through Crittenden.

Beneath and in the ice was a load of rock fragments which were moving southward. They were being ground over one another and over the bed rock, so that they were being reduced to clay by the scouring action of the ice, which worked somewhat like a great sandpaper. When the glacier disappeared, this material was left where it happened to be, and so a soil was deposited which was composed of clay and pebbles derived from various sources to the north. This till or boulder clay was dragged into many of the old valleys, either wholly or partially filling them, so that the streams have often been obliged to cut new channels in the shale. Sometimes these rock gorges end abruptly where the stream crosses or

flows in the old drift-filled valleys and then the shale wall is changed to one of till, in which the boulder clay is sometimes one or two hundred feet deep, as is the case in parts of the gulf near Westfield.

As the ice withdrew, with a south-facing front, it naturally interfered with all north-flowing streams. It formed a dam and caused many reversals of drainage. The St. Lawrence valley was occupied by the ice when the front had retreated north of the escarpment which partly encloses the grape belt. Therefore these north-flowing streams could not drain by the present outlet, but were pounded back and forced to take another place of outflow, and this was of course the lowest point in the enclosing hills, a point which was naturally higher than the present outlet. While the lake was held at its upper place of outflow it was building the upper beach, which has been called Sheridan beach. The outflow of this lake was then at Fort Wayne, Ind., into the Wabash, and the beach may be traced continuously to this outlet. However, in the east this beach comes to an end just south-east of Silver Creek; and near its eastern end there is a tract of moraine.*

To the southward of the town of Hamburg, on the road to New Boston, there is another morainic belt, and a second beach, which can be quite continuously traced from west of Silver Creek nearly to Hamburg, begins to disappear as this town is neared. The last place at which it could be distinctly determined is near Eden Church, southwest of Hamburg; but a third beach from the top passes directly through Hamburg, and has been found to disappear near Crittenden. In each case, as the moraine is approached, the beach becomes less distinct and finally can be traced no farther.

This shows that while these beaches were being built at their respective levels, the ice was standing at different places and was bringing materials which were being laid down at its front in the form of moraines. At first the ice front passed near Silver Creek and then the upper beach was made, while the outflow of the lake was past Fort Wayne. Then the edge of the ice withdrew for a distance until some lower outlet was formed, and again to a still lower, more northern point, when another and still lower outlet was

*This moraine has not been traced, so that nothing can be stated concerning its extension; but it appears in quite distinct development about two miles east of Silver Creek, extending nearly to the town.

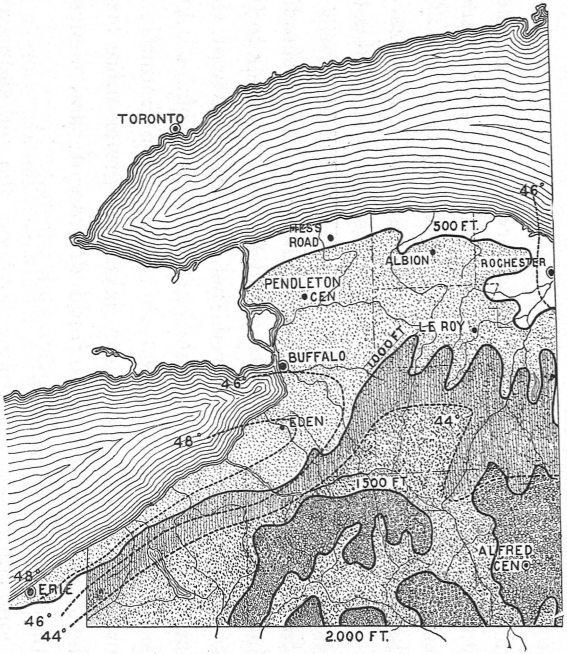
established. One of these last two outlets was past Chicago; but we know too little about the subject to state which one represents this stage, or to tell where the third outlet was.

At last the ice retreated far enough for the Erie basin to take its present outflow past Buffalo; but the valley of the St. Lawrence was still ice dammed, and Ontario was raised to the level of the overflow of the Mohawk valley. Thus temporarily the several Great Lakes had their level raised by ice dams; and during this time distinct shore lines were formed.

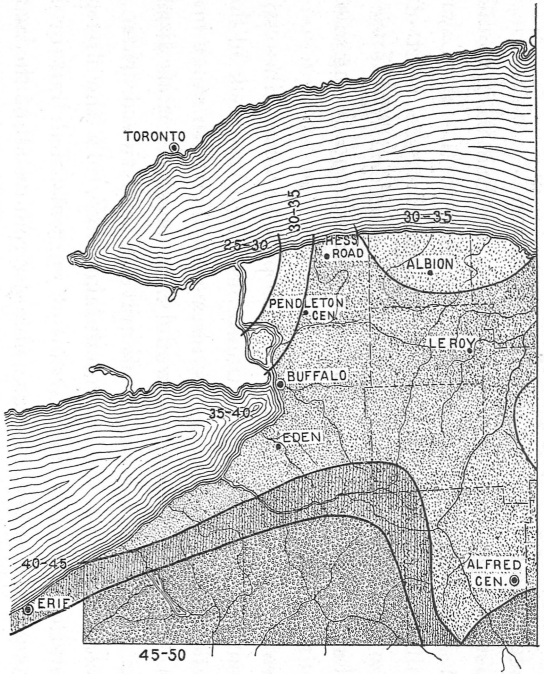
There are some differences from the present shore lines still to be accounted for. Why, for instance, are there no rock cliffs, but everywhere a series of beach gravels, a condition of so much importance to the grape grower? It would have been a serious disadvantage to have had the vineyards traversed by two or three rock escarpments like that of the present lake shore. In the first place, the question whether the waves and currents shall cut or build depends upon whether they are able to remove all of the material that they obtain by one cause or another. That is the reason why beaches are not built on some of the exposed head lands of the lake, while they are commonly present in the enclosed bays, and why the gravel accumulations opposite the mouths of the streams are more extensive than elsewhere.

There are various reasons why the waters of the ancient lake were less able to remove the materials furnished them than is the case with the present lake. As the ice was leaving the land, there was at first a time when no vegetation covered the clay soil, and when the whole surface was attacked by the rain just as a plowed field is to-day. Therefore the streams were given more materials to carry to the lake. In the second place, the rains must also have been heavier when the cold ice wall was melting and furnishing vapor to the air. Besides this, the streams entered the lake at the base of the hill, while now they flow for a mile or two over a plain. Another important reason is the fact that the shores were gradually rising. Therefore, for various reasons, the lake was given more materials than the waves and currents could dispose of, and hence they accumulated in the gravel ridges which we find.

A second important difference between the old shores and the present ones, is the fact that they are no longer horizontal. This is



71.—Average temperature for the year in degrees Fahrenheit. From report of the State Weather Bureau.



70.—Rainfall in inches, giving total for the year. From report of the State Weather Bureau.

due to a tilting of the land since the beaches were formed. There is abundant evidence that the land is now and has been in the past in a state of motion. Actual historic record proves this in several places, and geological study proves it in many more. Since the glacial period the movement in this part of the land has been that of tilting, with greater elevation in the northeast. Therefore these beaches do not show so great a change as they would if they extended in a more nearly north and south direction. The amount of tilting varies from place to place, but in the Chautauqua grape belt averages not far from one foot per mile.

A final question that we may ask, is how long ago this happened. To this no definite answer can be returned. A study of Niagara gorge, which has been formed since Lake Erie fell below the lowest gravel ridge, seems to show a period between 4,000 and 15,000 years. There is some reason for believing that the first is nearer to the truth than the last, and that it may even be a shorter period than this. Otherwise it would be difficult to account for the fact that these gravel ridges have resisted destruction so well. Nor can we state any more definitely how long it took the lake waters to build the beaches. They probably do not represent a great length of time, for materials were apparently rapidly supplied.

CLIMATIC CONDITIONS.

While the soil is a very important element in the value of the grape land, the climate is of even greater importance. Hence, while this study was not made primarily with the object of determining the climatic peculiarities of the belt, some features of a general nature were so pronounced that they attracted attention. The lake is a great modifier of climate. In the spring, by reason of the low temperature of its waters, it holds back the vegetation and this tends to keep it behind the ordinary frosts. Its very presence checks frost by moderating the temperature of the neighboring air. In the summer, the water tends to cool the air of the day and to keep the nocturnal temperature fairly high. During the fall, the water has been warmed by the summer sun, and the influence of this warm body of water lengthens the growing season and tends to keep off the early autumn frosts.

There are many other influences, but nothing of importance

can be stated excepting on the basis of a careful study extending over several years. The lake breeze of the day must moderate the daytime temperature; and the land breeze of the night may in some cases so keep the air in motion as to prevent frosts. That there is a marked influence upon climate as a result of the peculiar conditions of topography and neighborhood of water, is evident at the very first. The sketch maps (Figs. 70 and 71) show that the mean annual rainfall is greater on the escarpment than on the lake plain, and that the mean annual temperature of the hills is lower than that near the lake. During the disastrous frost of May, 1895, the vineyards in the grape belt, taken as an average, suffered less near the lake, while those farthest from the water were most injured. Still there were cases of vineyards near the lake that suffered considerably, while some on the escarpment were scarcely touched.*

MOST FAVORABLE PLACES FOR THE LOCATION OF VINEYARDS.

As has been said, there are two factors in the problem which deals with the reason for the conditions in the grape belt, one climatic the other geologic. The climatic features are dependent upon the location near a large lake, and the presence of the bounding escarpment, which confines this influence to a narrow limit. In the eastern part, where the escarpment is relatively low and far from the lake, the influence of the lake is much less distinct.†

*The behavior of this frost was altogether remarkable, leaving some districts or vineyards almost unharmed, and nearly ruining the crop in others, while even in the same vineyard these extremes were sometimes noticed. This was probably chiefly due to eddies of the air, for even though air is almost quiet, it is still in uneven motion. One may see this illustrated on a calm day by noticing the movements of a column of smoke. The air, being invisible does not reveal these movements, and we become aware of them only when the conditions are exceptional, as when a frost is dealing out destruction to vegetation. The condition of the ground also affects the frost, and the question whether it is dry or moist, freshly plowed or turf covered, whether there are trees or pastures or plowed ground in the neighborhood, all have their influence; but this subject has never been properly studied, and it is not possible to state just how these differences affect frost action.

†This was well illustrated during a frost in the middle of September, 1895. At Westfield there was no indication of a frost, east of Silver Creek signs of its effect began to appear, and at Hamburg, the frost had done considerable damage to the more delicate forms of vegetation.

This is the main reason why the grape belt does not extend far east of Silver Creek. Even in the distance of a few miles, from the lake to the crest of the hill, where grape raising practically ceases, there is much variation in climate, as has already been pointed out.

Considering the three belts of soil from the standpoint of their adaptability to grape raising, the hillside soils are of least value, the climate is least favorable, and the surface configuration of the land is least adapted to this industry. The lake clay soils are of poorer grade than the gravel soils, but the climate is in favor of this belt. The defect of soil texture, which is against most of the lake clay soils, can be readily overcome by a very little intelligent study of the conditions; and so there seems to be no reason why the vineyards should not extend from the base of the hill to the lake. Indeed, the favorable climatic conditions make this industry possible even on the hillsides for a considerable elevation above the plain.

INFLUENCE OF THE GRAVEL RIDGES.

One of the most striking influences of the gravel ridges is upon the roads. For the greater part of the distance, each of the two main gravel strips is occupied by a road which is remarkable for its levelness and for the gravelly material which makes the excellent roadbed. Travelling is therefore extremely easy, and it is very probable that this natural roadway was the site of an Indian trail. Even the position of the towns is often determined by the gravel ridges. Several of the villages and towns, east of Silver Creek, are (including Hamburg) on the gravel; and west of this town, in New York, every place of any size on the Erie shore (excepting Dunkirk, which is so situated because of its port) is located on the gravel ridges. This is true of Sheridan, Fredonia, Brockton, Portland, Westfield and Ripley.

Another important influence is upon the water supply. The gravel furnishes a reservoir through which the water percolates along the junction with the clay; and at the base of the gravel ridges, springs occur where the line of junction nears or reaches the surface. So important is this underground reservoir that not only are the houses on the ridges easily supplied with water, but houses below the beaches are in some cases furnished with water from this source.

Of course the most important influence is upon the fruit industry, and this has already been discussed in sufficient detail. Two or three suggestions may, however, be in place. There is no reason why the fruit district should not extend beyond Silver Creek. For several miles beyond that town the conditions are favorable, though they become less and less so as the distance increases. Another point is the feasibility of increasing the range of crops. The climate and soil are well adapted to all kinds of fruits which are common to this latitude; and one would suppose that even the tobacco plant might be profitably grown in a region so peculiarly favored. Almost all conditions have conspired to make this one of the most favored spots in the state.

R. S. TARR.